EXPERIMENTAL INVESTIGATION OF A THICK LAMINAR AIRFOIL

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Background of the Experiment

Before proceeding with a description of the experiment, it might be well to comment briefly on the various considerations affecting the choice of thickness to chord ratio (t/c) in the design of sailplanes. The recent publication of Reference 1 provides an excellent review of the world's sailplanes and indicates the present design trends. Picking at random an international bevy of a half-dozen open class, high-performance sailplanes for which weight breakdowns are given, we find the wing weight to average 46% of the maximum permissible flying weight. The weight of the bending resistant maternal is an appreciable percentage* of the wing weight and will vary roughly inversely as the square of the thickness. It can be seen that increases in the wing thickness ratio will result not only in reduction of wing weight (for a fixed planform), but also in appreciable reduction in gross weight. Conversely, for a fixed flight wing loading, increase in thickness ratio will permit increase in span and aspect ratio with attendent increase in performance. Looking at our international squadron, we find wing spans increasing from the American RJ-5 (55) German Zugvogel (56) Swiss Elfe M (57.4) British Skylark 3B (59.6) to the Italian Eolo 3-V-1 and Yugoslavian Meteor with 65.6 feet. Aspect ratios are all between 20 and 25. The root chord thickness ratios vary all the way from 13.3% of the remarkable Elfe to 20% for the Skylark. It should be noted that the Elfe, in spite of its thin wing and wood structure, has very nearly the same ratio of wing weight to maximum flying weight as the Skylark, indicating the gains possible through meticulous care with design and structural refinement. Another example of possible gains through parting with convention is the present international championship sailplane, the HKS-3. Here the contour advantages of a plywood skin have been successfully bonded to a weight saving spar of aluminum, resulting in a ratio of wing weight to maximum flying weight of 0.382. To return to our theme, even with these structural advancements, the use of higher thickness ratio would permit performance gains to be achieved in open class sailplanes, providing no aerodynamic disadvantages appear. In addition, the increased stiffness of a thicker wing should delay the onset of aeroelastic problems which threaten as the cruising speeds steadily increase in response to increasing aerodynamic refinement.

*Reference 5 gives a figure of 35% for the sophisticated metal structure of the Meteor.

Looking now at the aerodynamic considerations, we shall first investigate the cruising condition. Reference 2 provides a great deal of data on the influence of thickness ratio on both laminar and conventional sections. Unfortunately, the lowest Reynolds number for which data is given is 3 million, while 2 million would be more representative of the cruise condition for the mean chord of a typical high-performance sailplane. Reference 3 provides data over the entire range of interest to sailplanes, but for an insufficient number of sections for present purposes. We shall therefore use the 3 million data at a lift coefficient of 0.2 as our representative cruise condition. Figure 1 shows some interesting results. The conventional sections show an almost linear rise in cruising drag with thickness ratio, with the loss in performance becoming prohibitive at the really high ratios. The laminar sections not only show lower drag than the conventional sections at all values of t/c, but actually show a leveling off in drag for thickness ratios beyond 15%. This leveling off is accomplished by shifting the location of minimum pressure (and hence extent of laminar flow) progressively aft as the t/c is increased. Of course, even lower cruising drags could be obtained at low thickness ratios with far aft minimum pressure, but this would be unwise since the drag would be prohibitive in the circling condition.

An attempt was made to keep the above study practical by specifying that the sections chosen had also to provide a drag coefficient not greater than 0.01 at a lift coefficient not less than 0.9 for the circling flight condition as shown in the lower part of Figure 1. The condition was met by all sections except for the low drag series at 21% thickness. If data had been provided for the 66-421, the cruising C_D would probably have been 0.0054 and the circling condition would also have been met. In absence of this data, the 65-421 with slightly higher cruising drag and more than adequate circling performance and the 66-221 with lower drag but insufficient circling performance are shown in Figure 1 to bracket the desired condition. It should be noted that the circling data was again (of necessity) taken at 3 million RN, which is far from the correct value. Typical sailplane R in circling flight is more like 1 million.

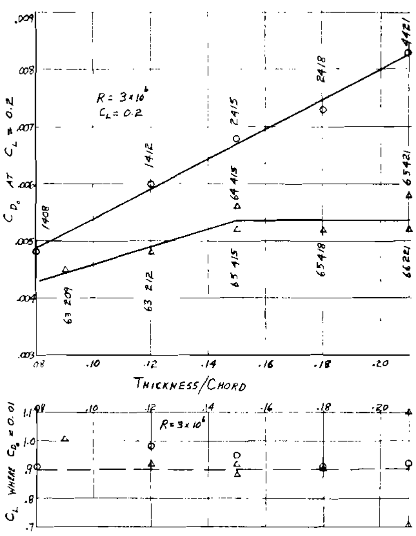

Fig. 1. Variation of Cruising Drag with Thickness/Chord Ratio.

The advantages of thick laminar airfoils are:

1. Delay of onset of aeroelastic problems to higher cruising speeds.
2. Lighter wing weight than a thinner section with same span and aspect ratio.
3. Increased span, aspect ratio, and performance at same wing loading.
4. Low cruising drag coupled with reasonable turning performance is indicated in Reference 2 at a Reynolds number of 3 million.
5. High degree of surface curvature helps to stabilize the skin against waviness leading to lower secondary wing weight. Also the high